were sparingly found; more common were *Œnothera cæspitosa*, Nutt., and *Œ. albicaulis*, Nutt., the latter extending as far as to Muskoda station east of the Red river. Much more rare was *Œ. Missouriensis*, Sims. *Gaura coccinea*, Nutt., was very abundant.

Three species of *Cactaceæ*, *Mamillaria vivipara*, Haw., *Opuntia Missouriensis*, DC., and *O. Rafinesquii*, Engelm., were plentiful. *O. Missouriensis* was first observed, in going westward, on the hills around Mandan.

The *Umbelliferæ* were mostly represented by species of *Peucedanum*, *Cymopterus* and *Musenium*. Of these only one, *Peucedanum nudicaule*, Nutt., extends as far east as Minnesota.

On the Formation of Starch in Leaves.

In a recent communication to the *Arbeiten des Botanisches Institut*, in Wurtzburg (Bd. III), Prof. Sachs gives the results of his work during the past summer in connection with the above subject. The investigations were made with the object of determining the formation and disappearance of starch in the leaves of plants growing in the open, and under normal conditions of vegetation, and were carried on chiefly during the months of June, July and August on a large number of Dicotyledons from various families. Some twenty-two years ago Prof. Sachs showed that the presence of starch in chlorophyll grains could readily be detected by means of the now well-known iodine test, a modification of which was employed in these researches.

If fresh, green leaves are plunged in boiling water for ten minutes or so, certain soluble substances are extracted, but the starch and coloring matter of the chlorophyll grains remain in the still unbroken cells of the mesophyll. A short immersion in alcohol now removes the green coloring matter and certain bodies soluble in alcohol, leaving the starch behind in the colorless tissue. The presence of acids affects the degree of whiteness of the decolorized leaf; and the decolorization proceeds more rapidly in sunlight or warm alcohol than in the dark and cold. Leaves of *Tropœolum* may be rendered completely white, like writing paper, in two or three minutes.

If the decolorized leaf be now placed in a strong solution of iodine in alcohol, the presence or absence of starch may be demonstrated in a few minutes. If no starch is present, the cellular tissue simply presents the well-known yellow color; if a large quantity of starch exists in the cells, the tissue appears blue black,

the venation appearing as a pale network in the dark ground. Paler colors result if but little starch is present at the time of the experiment.

It will readily be seen how useful the above method is for the purpose of demonstrating the absence of starch from etiolated leaves, the white portions of variegated foliage, etc , and the sequel shows that the method affords means of obtaining far more delicate results, without the trouble of a microscopic examination.

In the first place the same leaf may be found to contain very different quantities of starch at different periods of the day, or according to the weather; and secondly, the increase and decrease of the quantities of starch in a given leaf may be very rapid.

Sachs showed long ago that if a plant is placed in the dark, starch disappears from the leaves; and it has also been known for some time that if a piece of tin foil is placed on a leaf, the covered portion forms no starch although the parts exposed to light may become filled with that substance. Moreover, Kraus showed how very rapidly starch can be formed in direct sunlight.

Sachs now demonstrates on a number of plants that the starch formed in the leaves during the day may disappear completely during the night, and that the leaves shown to be full of starch in the evening may be quite empty of starch the next morning. This depends upon the temperature and health of the plant, but occurs normally during the summer in plants growing in the open. A large number of experiments are given in support of this, showing how the rapidity and completion of the process depends upon the weather.

The experimental proof is very simple. A leaf is halved longitudinally at night, after a fine sunny day, and the excised half is shown to be filled with starch by the iodine test described; the remaining half is tested early next morning, and shows at once if any material diminution has occurred during the night. A simple and obvious modification of this experiment gives an idea of the quantity of starch formed between sunrise and sunset. The half leaf tested before sunrise shows no trace of starch; the other half left on the plant during the day is found to be more and more filled with starch towards the afternoon.

Some curious results were arrived at as to the effect of growing parts on the rapidity of the emptying of the leaves; some of these matters still require investigation.

Differences in the weight of the leaves and in the intensity of the color produced by the iodine test, as well as some other observations, lead to a better understanding of a fact already known

generally, viz., that the starch disappears from the leaves in the form of glucoses, which travel by way of the vascular bundles into the stems, and thus pass to the places where they are used up in growth.

Some very telling observations were made in this connection, and the dependence of the processes on temperature again show forth clearly.

These results lead to the conclusion that the process of metamorphosis into glucoses and translocation of the products of assimilation are also going on during daylight, though they are less evident, because more starch is then being formed and accumulated than is abstracted at the time. Moll proved that such is the case by exposing leaves to the sunlight, but in an atmosphere devoid of carbon dioxide, the starch already in the leaves disappeared and no more was formed to replace it. Sachs repeated Moll's experiment, and proved the correctness of his conclusions by means of the iodine test. Half leaves were shown to be full of starch; the companion halves were put into closed atmospheres, deprived of carbon dioxide by means of potassium hydrate, and were exposed to sunlight. In an hour the latter halves were tested and found to be nearly emptied of starch. Other experiments proved that depletion occurred in a few hours, the time depending on the temperature.

Further experiments demonstrate that the starch travels in the form of glucoses in all the above cases, but it is not proved whether the metamorphosis is effected by forces in the chlorophyll grains themselves or by means of diastatic ferments in the cells of the leaf.

Perhaps the most ingenious part of the paper is that which now follows. It is well known that Weber's patient and thorough researches on the energy of assimilation led to two important results among others: (1) that the quantity of starch formed by a certain area of leaf surface in a certain time may be relatively very large, and (2) that different plants probably differ specifically as to the quantity of starch formed in their leaves.

Sachs proposes to apply his method to the solution of this question, i. e., how much starch is produced in, say one square meter of leaf surface by assimilation during, say ten hours of bright sunlight? The great difficulties in Weber's researches were connected with the enormous labor necessary to measure the leaf surface accurately.

Sachs resolved the matter in a manner which we may summarize thus: He cut off portions of large leaves found to be

empty of starch, measured them rapidly by laying them on pieces of board cut to the size of one square meter, and weighed the measured portions very rapidly. Certain precautions as to the area of fibro vascular bundles, the possibilities of absorbing hygroscopic moisture, etc., may here be passed over. Supposing these portions of the leaves to be estimated in the morning, a quantity of the same leaves of equal area gathered in the evening was then compared, and the increase in weight gives the quantity of starch formed in the interval. By weighing large areas, and frequently, and by paying attention to the times and other circumstances, a large number of results were obtained, showing that the quantities given by Weber, for instance, are within the mark. Of course these results are not absolute. Starch is being changed into glucose, and passing away during the day, and some must be burnt off in respiration; moreover, a certain minute quantity of mineral ash should be allowed for. Of course it is an assumption that equal areas of mesophyll of the same leaves contain approximately the same amount of substance; nevertheless, if a large number of experiments are made, the error is probably small.

Experiments were made to show both the quantity of starch which disappears during the day and the quantity which is formed during the day. A few of the numbers may be given. In *Helianthus*, 9.64 grms. of starch disappeared in ten hours from one square meter of leaf-surface.

In the same plant 9.14 grms. were formed in the same time by the same area of leaf-surface.

In another case *Helianthus* was used, but the leaves were removed from the stem to prevent the passage back of the starch from the mesophyll into the stems.

A square meter was found to produce starch at the rate of 1.648 grms. per hour.

By combining his experimental results and taking note of all the circumstances, Sachs concludes that 20 to 25 grms. of starch may be produced per day by one square meter of leaf-surface as an ordinary occurrence, and these numbers are not only not excessive, but experiments show that there are plants which produce much more than those investigated here.

Some remarkably interesting and important results follow from the consideration of these experimental data.

They explain why plants are so vigorous during warm nights following upon hot, bright days. The more readily the products of assimilation (formed in large quantities during the day) can pass into the growing organs, the better these are nourished, etc.

Leaves used as fodder, etc., must differ in nutritive value to a very great extent if their starchy contents vary so largely during the day and night; it thus becomes of primary importance whether such leaves are gathered in the morning or the evening, in cold or warm weather, etc. The same applies to *tobacco* and *tea*, etc. It must make a vast difference to the smoker whether his tobacco abounds in carbohydrates or is relatively richer in the alkaloids. It appears that tobacco is habitually cropped in the morning in some countries, a fact which suggests what experience has already shown that a difference in the quality exists; it will be interesting to inquire further into these matters.

Sachs' results will also materially affect the physiological value of the analysis of leaves. Some of us know how great are the variations met with in the analysis of the ash contents of leaves of the same plant. It is clear that in addition to the age of the leaf, the soil, manure, etc., it is important to know the amount of starch present. It can not but happen that the mineral matters ebb and flow as well as the starch. The analysis of leaves will also be more valuable for the purposes of physiology if the numbers are stated not in simple percentages, but in terms of one square meter of leaf-surface.

The above brief summary of the results obtained by Prof. Sachs by no means does justice to the beauty of his methods, and the masterly way in which they are carried out; it must be admitted by all who understand the value and importance of this work that it is worthy of the great pioneer of vegetable physiology. Moreover, it suggests several matters which require further investigation, and no doubt would yield valuable results to those fortunate enough to have a botanical garden at hand.—*H. Marshall Ward, in Nature, XXIX., 554.*

GENERAL NOTES.

Necrology.—AUGUSTUS FENDLER died on the island of Trinidad, November 27, 1883, at the age of seventy-one. This we learn only at the present date, by a memorandum which was found on the table of the lamented Dr. Engelmann who was so soon to follow him. Fendler was born in Eastern Prussia, somewhere near Königsberg, received a good ordinary education, came to this country not far from the year 1840, was selected by Dr. Engelmann and the present writer to make a botanical collection in the northern part of New Mexico on the occasion of the movement of the United States troops to Sante Fé in 1846. Afterwards (1856-7) he, with a younger brother, migrated to Tovar, a German